The Scientific Selection of Explosives for Coal Mining*

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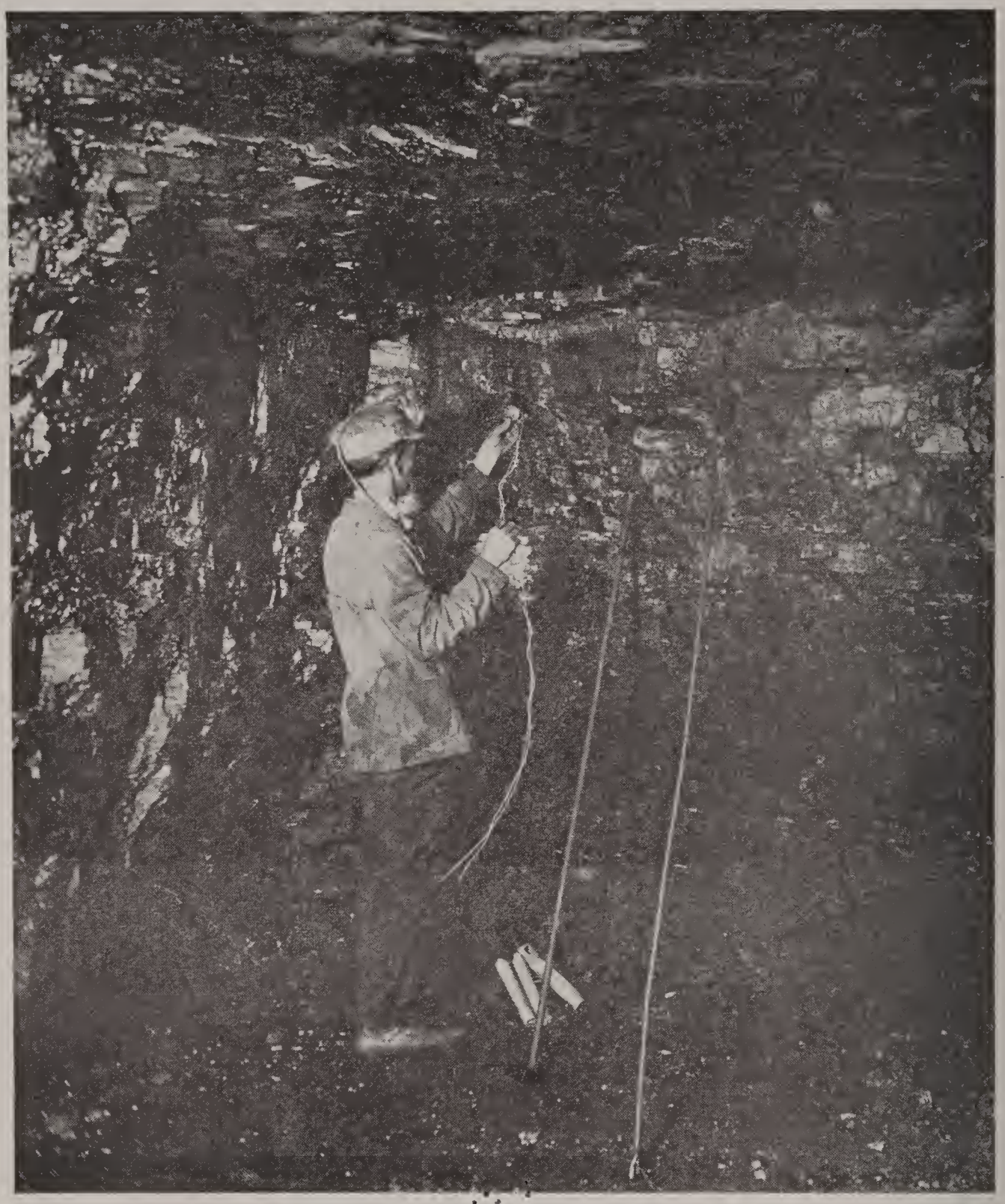

GOOD BLASTING PRACTICE

The coal has been undercut and the dust removed. The miner has an electric lamp and is using a permissible explosive, and electric detonators. He will tamp the charge well, using for stemming, "dummies" filled with moist clay.

THE SCIENTIFIC SELECTION OF EXPLOSIVES FOR COAL MINING

By

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EARLY DEVELOPMENT OF EXPLOSIVES

UNTIL the 19th Century the only explosive in practical use was ordinary gunpowder, a mixture of saltpetre, charcoal and sulphur. The latter two materials have been known from time immemorial, but the first reference to saltpetre is found in the writings of a Spanish Arab about 1225 A. D. The knowledge that these three materials would produce an explosive was discovered by Roger Bacon, and is referred to in his writings about 1249 A. D. The real development of gunpowder came with the invention of the gun about twenty-five years later. However, almost three hundred years elapsed before powder was used as an agent for mining and excavation work.

The process of manufacturing gunpowder has not varied much since that time except in improving machinery, increasing capacity and producing a better and more stable product. The percentages of materials have changed a little from time to time, but by 1650 had settled to approximately the same percentages that are used today, viz: 75 % saltpetre, 15 % charcoal, and 10 % sulphur.

About 1850, experiments were made using nitrate of soda as a substitute for nitrate of potash or saltpetre. The use of nitrate of soda for a blasting and mining powder rapidly developed. It has displaced the saltpetre powder for most industrial work. The usual formula for blasting powder in use today is 72 % soda; 15.4 % charcoal and 12.6 % sulphur.

Dynamite was first introduced by Alfred Nobel, a Swedish engineer, in 1866, after numerous accidents had resulted from the use of nitroglycerin alone. Nobel discovered that by mixing nitroglycerin with kieselguhr, an absorbent earth, it became safer to handle. Modern practice in the United States has eliminated kieselguhr for an absorbent and substituted nitrate of soda, nitrate of ammonia, wood-pulp, flour, etc., which give an active "dope", that is, one that will assist in the explosion instead of acting as an absorbent only, as is the case with kieselguhr.

Since its introduction, dynamite has replaced blasting powder in practically all underground metal mining and in much surface blasting such as quarry work, where hard rock formations are encountered and a quick shattering explosive is desired.

INTRODUCTION OF PERMISSIBLE EXPLOSIVES

The principal objection to the use of black powder in coal mines is the long, hot flame which it produces upon explosion. On account of this fact it readily ignites gas or dust, which occur in so many coal mines. Many disasters have occurred as results of explosions of gas or dust and in mines where either of these substances occur in appreciable amounts, the use of black blasting powder introduces an additional element of danger.

When the Federal Government in response to the widespread interest awakened by a succession of mine disasters, authorized in 1908 an inquiry into the cause of mine explosions, the Secretary of the Interior, James R. Garfield, decided that full advantage should be taken of the results of similar inquiries that had been in progress in foreign countries. Accordingly, at his request, representatives were sent by three European Governments to cooperate with the United States Geological Survey in studying conditions in this country. As a result of their examinations they framed a series of recommendations which were embodied in a report and distributed among the coal operators of the country. These recommendations, bearing on the subject of explosives were as follows:—

"(1) We recommend that the Government of the United States examine the explosives now and hereafter used in mining, with a view to eliminating the more dangerous explosives and to improving and standardizing such explosives as may be considered most suitable for such use, these to be designated by the Government 'permissible explosives.'

"The term 'permissible explosives' is suggested for the reason that no explosives are entirely safe, and all of them develop flame when ignited; and we advise therefore against the use in the United States of the terms 'safety explosives' or 'flameless explosives', as these terms may be misunderstood and this misunderstanding may endanger life.

"(2) We recommend that the operators and miners of coal use only such explosives as are included in a list of permissible explosives, when the same has been published by the Government, in all mines where there is risk of igniting either dust or gas, selecting that one which their own experience indicates can be used to the best advantage under local conditions.

"(3) We also recommend that investigations be conducted to determine the amount of charge of such permissible explosives which may be used to the best advantage under different conditions, with a view to reducing danger to the minimum."

The same committee made additional important recommendations concerning carrying the explosives into the mines; use of explosives in the mine; keeping the mine roadways clean; wetting the coal dust; special precautions for mines containing gas; use of electricity and miscellaneous precautions, all of which may be found in Technical Paper No. 21 of the U. S. Bureau of Mines. These recommendations are as important and applicable to present conditions as they were at the time they were written about ten years ago. Undoubtedly the presentation of these specific recommendations to the coal mining industry of the United States and their adoption to such a large extent marks one of the greatest forward steps that has ever been made in coal mining practice in this country.

In addition to publishing recommendations mentioned above, the Government established a testing station at Pittsburgh, Pa., in 1908. This station is now under the charge of the Federal Bureau of Mines. Before the station was opened, a statement of the requirements that the explosives in question would have to satisfy was drawn up and sent to manufacturers.

The lists now published by the Bureau contain the names of explosives that have passed the Bureau's permissibility tests, together with data regarding their speed, strength, etc.

An explosive is officially termed a permissible explosive when it is similar in all respects to the sample that passed certain tests of the Federal Bureau of Mines, and when it is used in accordance with the conditions prescribed by the Bureau.

These conditions are as follows:—

(1) That the explosive is in all respects similar to the sample submitted by the manufacturer for test.

(2) That detonators, preferably electric detonators, are used of not less efficiency than those prescribed.

(3) That the explosive if frozen, shall be thoroughly thawed in a safe and suitable manner before use.

(4) That the quantity used for a shot does not exceed 1½ pounds (680 grams) and that it is properly tamped with clay or other non-combustible stemming.

The following statements were made in a recent address by the General Manager of a large coal mining company operating in West Virginia:

"A great many steps have been taken by our company along safety lines for several years and we have decided that the training of our men along safety lines is just as important as any other branch of the mining industry.

"Our first step was to eliminate the use of black powder for blasting purposes, and this we did about six years ago, adopting in its stead a permissible powder. I am advised today that since permissible powder was put into use we have reduced the accidents that were formerly caused by explosives about 75 per cent. If we were to eliminate the accidents that are caused by the use of short fuses by the miners the reduction would be considerably greater than 75 per cent."

Classes of Permissible Explosives. Permissibles are divided into five groups, two of which are important, namely, the Ammonium Nitrate class and the Nitroglycerin class.

The base or principal ingredient of the Ammonium Nitrate class is, as the name implies, Nitrate of Ammonia. This together with some carbonaceous matter and small percentage of nitroglycerin, to act as a sensitizer, constitutes the explosive. The slower varieties have certain salts added to change the quickness according to the requirements in different sections of the country. Because of the low specific gravity of Nitrate of Ammonia which is the principal ingredient, it is more bulky than ordinary dynamite. For example,

SAFETY

The General Manager of a Company operating a large number of coal mines including the one in which this striking photograph was taken, stated recently that after permissible explosives were introduced, the number of accidents in their mines caused by explosives had been reduced 75 per cent.

A DAILY SUPPLY MAGAZINE

It is usually necessary to keep on hand at the mine a sufficient quantity of explosives to meet the daily requirements. To ensure safety, a well built magazine like the small one shown above should be used. This Pennsylvania mine produced more than 360,000 tons of coal during 1920 without a single fatal accident.

there are about 200, 1¼″ x 8″ cartridges in 100 lbs. of ordinary dynamite, while there are from 270 to 310 of the same size cartridges per 100 lbs. of the various grades of Red H, a permissible of the Ammonium Nitrate Class.

The main ingredient of the Nitroglycerin Permissible, is indicated by their name, nitroglycerin.

The Ammonium Nitrate Permissibles are in our opinion, more efficient in the majority of cases than the Nitroglycerin grades. The Ammonium Nitrate permissibles are the safest as regards handling and use. The principal constituent, Ammonium Nitrate, is not waterproof, but to overcome this, all cartridges are dipped a second time in paraffin after filling and, in some cases the ammonium nitrate itself is made more water resisting by special treatment. These permissibles can, therefore, be used satisfactorily in wet work if care is taken not to split the cartridges when placing them in the bore hole.

SCIENTIFIC SELECTION OF PERMISSIBLE EXPLOSIVES

One of the Federal Bureau of Mines Bulletins states that the Unit Deflective Charge tells more about the coal-getting qualities of a permissible than any one figure. On account of the various factors

that determine the strength of an explosive, there is no one figure which will express it absolutely, but the Unit Deflective Charge comes nearer to representing strength than any other.

In determining Unit Deflective Charges, the Pittsburgh Testing Station of the Bureau takes ½ lb. of Standard Bureau of Mines Straight Nitroglycerin dynamite and fires this in a cannon that is part of a ballistic mortar apparatus. When the cannon is fired the muzzle is against a pendulum. The force of the explosion directed against this pendulum sets it in motion. The maximum arc through which it swings is automatically recorded. The distance that the pendulum is moved by this half-pound of Standard 40 % Dynamite is taken as a unit distance, and the other explosives are then tested to determine how much of each of them it takes to move the pendulum the same distance. The amount of any permissible required to move it this unit distance is called its Unit Deflective Charge. Naturally, the stronger the explosive, the smaller the charge required. It is important to bear in mind the fact that the Unit Deflective Charge is the amount of an explosive (by weight) required to perform a standard amount of work, because otherwise the wrong idea might be conveyed. Always think of the Unit Deflective Charge as the amount of explosive necessary to do a certain piece of work, as for instance, to swing a pendulum a certain distance. It will then be evident to you that the less it takes, or the lower its Unit Deflective Charge, the stronger is the explosive.

There is another important factor which enters into the performance of a permissible. This is its quickness, which is designated as "Rate of Detonation", that is to say, the velocity with which the wave of detonation travels through the explosive. The higher the rate of detonation, the quicker the explosive.

Other things being equal, a fast powder has greater smashing effect, is more local in its action, and is more apt to bring down its burden unless it is too quick for the material, in which case it will simply make a pot hole.

A slow powder on the other hand produces a heave rather than a quick blow, and its force is apt to spread out and exert itself over a large area.

Strength and quickness almost entirely determine the breaking qualities of an explosive. Therefore, the Unit Deflective Charge and Rate of Detonation of a permissible explosive give a good idea of what it may be expected to do.

In comparing figures for Unit Deflective Charges and Rates of Detonation it should be borne in mind that the difference of only a few grams in the Unit Deflective Charges or several hundred feet per second for Rate of Detonation should not be taken into consideration. It might be caused by slight variations in the sample or in the apparatus used for testing. Where there is a marked difference in the qualities of the explosives, however, the figures will indicate it plainly by a difference of appreciable size. It is, therefore, a matter where one must use reasonable judgment.

In addition to strength and quickness some points to be carefully considered in choosing a permissible for any particular work are, nature of fumes produced, water resisting qualities and number of cartridges obtained in any given weight.

The fumes from Ammonium Nitrate permissibles as a rule contain a less percentage of poisonous gases than those of the Nitroglycerin class. This is an important point in favor of the former.

The Nitroglycerin permissibles are more waterproof than the Ammonium Nitrate grades. However, the latter are used successfully in wet work if care is taken that the cartridges are not split when charged in the bore hole. The extra dipping in paraffin and the special treatment given the ammonium nitrate, protects the powder from the action of water for a considerable time.

EFFECT OF PERMISSIBLE EXPLOSIVES ON SIZE OF COAL

Rutledge and Hall state in Bulletin 10 of the Bureau of Mines: "When a mine makes the change from black powder to a permissible explosive there may be a slight increase in the proportion of fine coal made; but a considerable part of this increase must be laid to the miners' lack of experience with the new explosive. Miners must become accustomed to the use of a new grade of black blasting powder before they can get good results with it, and each miner must learn by experience how best to shoot any coal bed that is new to him. In like manner, a miner must become accustomed to using permissible explosives."

The same writers conclude that if a miner uses permissible explosives with exact judgment, the proportion of lump coal that is produced compares very favorably with what would be obtained by the use of black powder.

THE PROPER EXPLOSIVE PRODUCES MORE LUMPS

Different coal seams vary so much in physical characteristics, that the most suitable explosive can be chosen only after a careful study of all local conditions. The strength and quickness of the explosive have an important bearing on the market value of the coal.

It is also stated in Bulletin 10 of the Federal Bureau of Mines that according to information received by Government officials, from districts where the cost of using permissible explosives has been carefully kept, there is little, if any difference in the cost of blasting a ton of coal, whether permissible explosives or black powder is used. In some instances we find the cost of using permissibles will exceed that of black powder. However, the additional safety obtained by the use of permissible explosives is often sufficient to warrant their introduction. In some cases the greatest opposition to such a change is found amongst the miners themselves, who may object to any change from old familiar methods. In this event there is an excellent opportunity for those in charge of operations to educate the miner to the personal advantages he will derive in the way of increased safety, convenience in handling, and better fumes, by making this change.

FACTORS AFFECTING EFFICIENCY

No attempt has been made in this paper to describe the best methods of priming, loading and firing explosive charges, because to properly cover those subjects would require a long discussion.

However, there are certain points which it will be well to emphasize briefly, as they have an important bearing upon the efficiency obtained in the use of permissible explosives.

(1) Use of Strong Detonators: Nothing weaker than a No. 6 detonator should ever be used with a permissible explosive, and the use of No. 8 detonators will more than repay the difference in cost by the increased efficiency obtained from the explosive.

(2) Effect of Stemming on the Efficiency of Explosives: The use of good stemming material properly tamped is necessary in order to obtain good results with permissibles.

The U. S. Bureau of Mines has conducted numerous experiments along this line and the following conclusions are given in Technical Paper 17:

"The increase in efficiency from the use of stemming varies considerably with different explosives. With slow-burning explosives such as black blasting powder, a large quantity of stemming is required for effective results, and the greater the quantity of stemming used, and the more firmly this stemming is tamped into the bore hole, the greater is the useful work done by the shot. Since the

BLASTING AN EIGHTEEN FOOT SEAM

The result of a shot made with Red H. Permissible explosive at a Utah Coal Mine. This coal seam is about 18 feet thick. A bottom heading is first mined and the top bench shot down latter.

Note the high percentage of lump coal obtained.

stemming in a drill hole is seldom as firm or unyielding as the surrounding rock, as much stemming should be used as can be placed in the drill hole. Tamped moist clay or some similar plastic material is the best stemming for all explosives and dry pulverulent material, such as dry clay or coal dust is least efficient. The use of the most efficient stemming materials may increase the useful energy of a shot 93 per cent; the use of the least efficient stemming materials may increase that energy 60 per cent. Accordingly it is clear that the use of stemming is necessary when the maximum useful effect from an explosive is desired."

It may be seen, therefore, that while the selection of the proper explosive has an important bearing upon blasting costs and grades of

coal produced it is further necessary to employ proper methods in the use of these explosives in order to obtain best possible results.

SUMMARY

Given the problem then of choosing the explosive most desirable for any particular set of conditions the following points should be considered:

Safety.—This is becoming more and more a primary consideration with an ever-growing number of coal mining companies. Viewed from the safety angle, permissible explosives possess a decided advantage over black blasting powder. In mines where dust or gas are found in appreciable amounts the use of a permissible explosive is usually specified by the mine inspector. Even in mines where there is little danger from dust or gas explosions, the permissible type of explosive is safer and more convenient to handle than black powder. Moreover, the fumes resulting from the detonation of most permissible explosives, when properly tamped, are better than those produced by black powder.

Strength and Quickness.—With black blasting powder the only factor to consider under this head is quickness which varies with the granulation. The coarser the granulation the slower the powder, so that a fair range of speeds may be obtained by selecting the desired one of the seven granulations in which black powder is usually marketed.

With permissible explosives the problem is a little more complicated but with the number of grades manufactured and the data available a closer selection can be made.

The figure which most closely represents the strength of a permissible is its unit deflective charge, and it should be remembered that the smaller the figure for the unit deflective charge, the stronger is the explosive. Also remember that the difference of only a few grams in the unit deflective charges is immaterial, but from these figures for unit deflective charges, considered broadly, the relative strengths of permissible explosives can be accurately judged.

The "Rate of Detonation" designates the quickness of a permissible and here also, differences of a few hundred feet in velocity should not be considered, but the fact should be remembered that the greater the "Rate of Detonation" of an explosive, the greater is its shattering effect.

The physical characteristics of each coal seam and the purpose for which the coal is to be used are the governing factors in selecting

the explosive for mining it, and the strength and quickness of the explosive to be used are extremely important considerations if good results are to be obtained. These figures can be obtained for all permissibles from the publications of the U. S. Bureau of Mines.

Nature of Fumes Produced.—The fumes from the Ammonium Nitrate permissibles in most cases contain a less percentage of noxious gases than those of the Nitroglycerin class. When properly tamped, permissible explosives of the Ammonium Nitrate group give much better fumes than black blasting powder.

The question of fumes is important not only from the standpoint of the comfort and health of the miner, but it is also true that the actual amount of work a miner can perform is affected considerably by the kind of air he breathes in his working place.

Water Resisting Qualities.—While the Nitroglycerin class of permissibles are more waterproof than those of the ammonium nitrate type, the latter may be used satisfactorily in nearly any kind of work encountered in ordinary coal mining operations. The double-dipping in paraffin affords an additional water-proofing for the Ammonium Nitrate permissibles.

Cartridge Count.—After the permissibles which have the proper quickness and strength are picked out, economy can sometimes be effected by a comparison of the number of cartridges of each for a given weight. If two permissibles will perform equally well, cartridge for cartridge, and one of them has a greater number of cartridges per box than the other, it is readily apparent that the mining company handling the powder and the miner using it will both save money by using the higher count permissible. This information can be obtained from the manufacturer.

Packing.—This is a quality of permissible explosives which is often a matter of individual taste. As a rule, the coal miner desires his cartridges well filled and not too hard. The powder should not be so hard as to make it difficult to insert the detonator, neither should it be so loosely packed that it does not completely fill the cartridge. The skill and care exercised in manufacture may often be judged from the manner in which the cartridges are packed.

HERCULES POWDER CO.

Manufacturers  *of Explosives*

ALLENTOWN, PA.	NEW YORK, N. Y.
BIRMINGHAM, ALA.	NORRISTOWN, PA.
BUFFALO, N. Y.	PITTSBURG, KANS.
CHATTANOOGA, TENN.	PITTSBURGH, PA.
CHICAGO, ILL.	POTTSVILLE, PA.
DULUTH, MINN.	ST. LOUIS, MO.
HAZLETON, PA.	SALT LAKE CITY, UTAH
HUNTINGTON, W. VA.	SAN FRANCISCO, CAL.
JOPLIN, MO.	WILKES BARRE, PA.
LOUISVILLE, KY.	WILMINGTON, DEL.